NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

(10)

JPRS: 16,072 OTS

7 November 1962

PROBLEMS OF SURGICAL TREATMENT FOR INJURIES CAUSED BY RADIATION

by A. Morczek and K. Neumeister

- East Germany -

U. S. DEPARTMENT OF COMMERCE
OFFICE OF TECHNICAL SERVICES
JOINT PUBLICATIONS RESEARCH SERVICE
Building T-30
Ohio Dr. and Independence Ave., S.W.
Washington 25, D. C.

Price: $1.60

F O R E W O R D

This publication was prepared under contract for the Joint Publications Research Service, an organization established to service the translation and foreign-language research needs of the various federal government departments.

The contents of this material in no way represent the policies, views, or attitudes of the U. S. Government, or of the parties to any distribution arrangements.

PROCUREMENT OF JPRS REPORTS

All JPRS reports are listed in Monthly Catalog of U. S. Government Publications, available for $4.50 ($6.00 foreign) per year (including an annual index) from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Scientific and technical reports may be obtained from: Sales and Distribution Section, Office of Technical Services, Washington 25, D. C. These reports and their prices are listed in the Office of Technical Services semimonthly publication, Technical Translations, available at $12.00 per year from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Photocopies of any JPRS report are available (price upon request) from: Photoduplication Service, Library of Congress, Washington 25, D. C.

JPRS: 16,072

PROBLEMS OF SURGICAL TREATMENT FOR INJURIES CAUSED BY RADIATION

[Following is a translation of an article by A. Morczek and K. Neumeister of the Institute of Radiation and the Radiotherapeutic Clinic of the Magdeburg Academy of Medicine (Director: Prof Dr med. habil. A. Morczek), published in Das deutsche Gesundheitswesen (German Public Health Affairs), Vol 17, No 30, 26 July 1962, Berlin; pp 1266-1270]

The construction of atomic power plants, the existence of nuclear arms as well as the increasing application to many areas of our life of natural and artificial radioactivity make it necessary that large circles of physicians become thoroughly acquainted with the prophylaxis and therapy of radiation damages. Precautionary measures instituted in nuclear plants and laboratories limit the employees' exposure to radiation to a minimum. Nevertheless these measures do not fully rule out the danger of radiation accidents. By radiation accidents we mean accidents which consist of injuries and simultaneous exposure to the effects of radiation.

Radiation can exert its action on the organism in the case of an accident in two ways:

1) Through irradiation from the exterior,
2) Through the absorption of radioactive substances by the organism (incorporation).

The two routes by which damage may be afflicted on the body may be combined with one another in various ways. High doses of radiation, reaching larger sections of the body or the entire organism, whether coming from the outside or from within the organism, bring about the acute radiation syndrome. Irradiations reaching a circumscribed area produce local radiation damages. The absorption of radioactive substances can take place in the following three ways:

1) Through the gastrointestinal tract;
2) Through the lungs;
3) Through the intact and/or injured skin.

In the case of a nuclear weapons explosion the mechanism of damage is fundamentally the same as in nuclear reactor accidents. The differences are only quantitative. In addition to irradiation from the exterior and incorporation of radioactive substances which affect individual organs or the whole organism, mechanical or thermal influences may cause injuries which further increase the possibility of wound-contamination and hence, of an additional incorporation by this route. In this way the number of possible combinations of radiation damages is greatly increased.

The extent of health damage caused by the incorporation of radioactive substances depends on a number of factors:

1) The amount of radionuclide absorbed;
2) The nature of the emitted radiation;
3) The effective half-life;
4) The route of absorption in the body;
5) The affinity of the radionuclide in question to given organs (pattern of distribution);
6) The relative susceptibility to radiation of the critical organ.

In function of these factors even small amounts of radionuclides incorporated in the organism can be dangerous.

Persons who have been exposed to a high dose of radiation or who had incorporated radionuclides through the gastrointestinal tract or the lungs, are sent to physicians who have been specially trained in nuclear medicine (Nuklearmediziner; "nuclear physicians"). In cases where injuries had also occurred it is necessary to resort first to surgical treatment undertaken in collaboration with the nuclear physician. In this paper we shall discuss the basic guiding principles to be adhered to in such cases.

The present methods of treatment cannot as yet be based on any wide experience in this area since luckily nuclear catastrophes have been very rare. Hence, the methods of treatment are still in the process of elaboration, while making use of data from different fields. Our knowledge of the surgical treatment of injured and radiation-damaged individuals is based on experiences acquired in Japan after the dropping of atomic bombs in 1945, on observations obtained in accidents in nuclear plants and laboratories, on clinical cases of therapeutic irradiations and on the results of animal experiments.

Finkel and Hathaway (10) report on rather frequent injuries in research laboratories as well as in clinical and technical isotope departments, caused by the incorporation of radioactive substances. These accidents led to the establishment of so-called decontamination stations staffed by physicians, physicists and specially trained auxiliary personnel for the treatment of radioactively contaminated wounds. Similarly, King (22) prescribed for the treatment of radiation-damaged persons special stations staffed by an appropriately trained group of physicians, physicists and auxiliary personnel. These stations should be equipped in such a way that in addition to the required medical and surgical treatment the staff may also perform measurements of radioactivity, above all measurements on the whole body after incorporations. During "slack periods", that is, period in which no cases of accidental injuries have to be attended to, the staff should devote itself to radiation-biological research.

Radioactively contaminated wounds are exposed to a local radiation stress. The latter can vary greatly and is dependent above all on the velocity of resorption. The extent of resorption by the wound depends in turn on the physical-chemical characteristics of the radiation source as well as on the nature -above all the vascularization- of the wound. Incorporation via open wounds usually proceeds very rapidly. In the case of large-size wounds it may equal the velocity of absorption following an intravenous injection (Graul (3)).

Foreman (4) reports that an assistant who had injured her finger with a glass splinter while working with a plutonium solution exhibited a relatively high radioactivity in the urine very shortly after the accident. Gustafson, Marinelli and Hathaway (9) describe an incorporation of Thorium-227. A member of the research group injured his index finger with a cutter that had been dipped two days before into a solution of Th-227 chloride. Immediately thereafter the α-ray detector counted 60-80,000 impulses per minute on the site of the puncture. After rinsing the wound with calcium disodium ethylenediamine tetraacetate (CaEDTA) and half-concentrated hydrochloric acid, the count was still 17,000 impulses per minute. After four days, in view of the high activity in the urine the thought arose that perhaps the mother substance Actinium-227 had also been incorporated, and accordingly the wound was excised and the patient treated with 1 g CaEDTA, administered intravenally. On subsequent activity testing with a 24-channel discriminator it was found that while the Th-227 had disappeared rapidly from the wound region, its rate of excretion from the body was very low. The daughter substance Ra-223, which because of its sufficiently high period was the only one of the decomposition products accessible to analysis, was found to have been resorbed from the wound rapidly and to have been excreted sooner than the Th-227.

The treatment of persons injured in radiation accidents should consist of the application of first aid and the earliest possible surgical intervention. The first aid should be administered by the staff of the isotope laboratory who must be appropriately trained. When an accident occurs the first thing to do is to determine the amount of radiation to which the victim was exposed or at least its order of magnitude. The next step is the decontamination of the victim, the instruments and the place of work. The contaminated clothes must be left at the place of work. The contaminated bodily areas should be washed as follows (Beck, Dresel and Melching (1)):

1) Three minutes' thorough washing of the area in question with lukewarm water and mild soap;

2) Eight minutes' scrubbing with the brush;

3) Activity check by means of counter;

4) Application of decontamination measures (see below);

5) After-rinsing with sodium sulfite or sodium citrate.

For the decontamination of smaller amounts of radionuclides titanium dioxide ("Dekontan") mixtures with barium sulfite and starches, as well as isotonic salt solutions have been found useful. In the case of a contamination by unknown radionuclides or by a mixture of radioactive substances it is recommended that the exposed skin area be cleaned with a mixture of titanium dioxide and N/10 hydrochloric acid. In the case of contamination with known radiation sources it is expedient to use appropriate precipitating agents. For the decontamination of hands and feet saturated solutions of $KMnO_4$ are most suitable. Heavy metal compounds, for instance uranium salts, may be eliminated by the addition of citrate to the wash water, since citrate ions form soluble complexes with heavy metals. For certain cases it is advantageous to use concentrated--circa 8 N--HCl, especially in regions where the skin is covered by a thick horny layer, or where the area of contamination is small (2). For mucous membranes sodium bicarbonate is a suitable cleaning agent (1,2).

Very interesting are the experiments with rats reported by Michon (12) in which it was attempted to carry out the elimination of radioactive impurities by means of ionotophoresis. In these experiments one of the electrodes was placed at any given point on the body and the other on the contaminated area of the skin. The best decontamination results were obtained with a solution of citric acid and sodium sulfate at pH 3. The current intensity was 0.3 mA/cm^2. In the case of a contamination with carrier-free P-32 in the form of phosphoric acid (anion), 95 percent of the contamination remaining after washing was eliminated by 0.5 $coulomb/cm^2$; with strontium-90 + yttrium-90 (cation) in the form of chloride over 80 percent was eliminated by 1 $coulomb/cm^2$. In all decontaminations one should make sure that the impurity is not carried into the wound or into the natural body orifices.

Medical help should be summoned even in the case of mild skin injuries. Treatment should always be carried out with particular haste and caution. The injured and radioactively contaminated skin area should be excised. thus preventing the penetration of radioactive substances into the circulation. Prior to this operation the magnitude of the radioactivity and the type of radionuclide should be ascertained, since the extent of surgical intervention will depend on these data. A close cooperation between surgeon and nuclear physician is indispensable in such cases (1, 2, 3). Preferentially, the performance of these tasks should be taken over by the isotope departments of the clinics. In regard to the method of wound treatment and excision it is not possible to set up any hard and fast rules. For purposes of guidance one may follow the advice of

Hug and Muth (8) according to which a radical intervention is necessary whenever more than 1 μc of a dangerous radionuclide has penetrated into the wound. For the inspection and control of the wound contamination a suitable instrument is a sensitive scintillation counter with a needle-shaped tip. With the aid of this instrument even the very smallest wound regions may be checked (1).

Before the excision the area of operation must be thoroughly cleaned. Finkel and Hathaway (10) recommend that the physician cover the wound with cellophane or apply a temporary suture in order to prevent any additional rinsing of radioactive substances into the wound. The decontamination of the operated region should be carried out with lukewarm water with the addition of detergents, and by scrubbing with a soft Perlon brush. It may be expedient to let the wound bleed for a short time so as to rinse out in this manner radioactive substances present in the blood stream. When the excision occurs on the extremities, the operation should always be followed by bleeding in order to reduce resorption (2, 3, 8, 10). The result of the surgical intervention must be verified by activity measurements. Before the final treatment a thorough cleaning of the wound from radioactive residues is indispensable. Regular blood- and urine tests for radioactivity are very essential. These tests provide during the course of treatment information regarding the extent of the existing nuclide incorporation and the necessity of further therapeutic measures.

Of these latter measures decorporation is the most important. The separation of radionuclides from the organism may be activated by chelate-forming agents (for example BAL, sodium citrate, EDTA, diaminodiethyl ether tetraacetic acid, diethylenetriaminepentaacetic acid), by zirconium salts or by polyphosphates. This subject is exhaustively treated by Graul (2,3), Catsch (5), Schmidt (7), Micke (8) and Spode (11). The after-care of the wound has to be attended to every day. In this connection one should pay particular attention to the radiation reaction of the skin and wound surface since it is possible that the wound had been exposed through the contamination to a particularly high local radiation dose.

In connection with this subject it would be interesting to know whether and to what extent a high local dose of radiation or even a radiation affecting the entire body, influences the wound-healing process, and whether on the other hand, the course of the radiation illness is influenced by the simultaneous presence of injuries. There are a few reports [illegible] on this subject. Katayama (13), working with guinea pigs, created in the animals wounds 13 cm in diameter and irradiated these wounds at various stages of their healing with a radiation dose of 120 r under conditions of depth therapy. At first there was an inhibition of the healing process. This was followed in the stage of transformation of the young granulation tissue into connective tissue by an acceleration of the healing process. The effects were the more marked in both directions the sooner the irradiation was carried out and the higher the magnitude of irradiated doses.

Further investigations were carried out by Bystreva and Sokolev (14, 15) They exposed guinea pigs to a total-body irradiation of 400 r and then caused skin wounds in the irradiated animals. Compared with a control group of non-irradiated animals the wounds healed slower. There were either no inflammatory reactions in the wound region or they set in belatedly. Regenerative processes were retarded, mainly because of the lack of proliferation of fibroblasts. In animals in which the radiation illness had taken a severe course, considerable bleedings occurred in the wound region, as well as necroses with secondary infections. No difference was observed in the healing process whether the wound was treated openly or with sterile bandages. In general the wounds of the irradiated animals healed 3-5 days later than those of the controls. The scars were harder and wider.

Very basic investigations were carried out by Baron and Vieten (23). These researchers exposed 500 guinea pigs to radiation and then created wounds in the skin of their flanks. During the healing process the wound size was determined planimetrically, at intervals. Different groups of animals were exposed to doses of 2 x 10 r four weeks before the creation of the wounds, and to 2 x 1 r, 2 x 10 r, 2 x 50 r or 2 x 100 r ten seconds after the wounding as well as 6 days thereafter. The results of these experiments may be summarized as follows: In the case of the irradiated animals there was a better contraction of the wound in the first few days. The irradiation led to a reduction of wound secretion, so that the wound was dry. After the sixth day and up to the 18th day there was a lag in the wound-healing process due to the inhibition of the growth of fibroblasts. The extent of retardation of the wound-healing process was in direct proportion to the dose or radiation administered. In the case of irradiation prior to the creation of the wounds, the latter healed with less epithelial expenditure or smaller scars. Only with low doses of radiation was there any enhancement of the wound healing and only when the irradiation occurred after the wounding. The sensitivity of the animals to total-body irradiation was greatly increased by the wounding.

Nickson and his research group (16) irradiated rats at one-day intervals with a total of 4 x 500 r under depth-therapy conditions and then caused in the animals deep abdominal wounds which included the peritonium. In contrast to other authors they reported that the wound-healing process ended on the same day in both irradiated and non-irradiated animals.

Nagoryanskaya (17) followed the course of wound healing in 42 pre-irradiated and operated patients. Up to a total dose of 1,800 r no influence exerted by the radiation on the healing process was clinically observable. With doses above 1,800 r the index of secondary healing increased. Prolongation of the duration of pre-irradiation to over 30 days and increasing the interval between irradiations and operation to over 60 days likewise led to a rise in secondary healing due to considerable sclerotisation of the skin blood vessels and surrounding tissues, with trophic disturbances being observed. Postoperative wound healing was influenced by the localisation of the pathological process, the site of the irradiated area and the extent of surgical intervention. Dmitrieva (24) undertook experiments aiming at the determination of the optimal time of wound treatment in the case of acute radiation syndrome. Simultaneously with irradiations of 200, 400 or 600 r, rabbits were wounded in the region of the snout. It was found that the best healing results were obtained when the wound was treated after 24 hours, while the results of treatment in the first few hours or 48 hours after irradiation were poorer due to appearance of necroses.

Tsanev et al (25) investigated in 700 white mice the influence of high radioactive doses on the healing process of wounds which were caused in the animals by several methods. In the case of the first group wounds 6 to 8 mm were created with a sharp scissors; in the second group the skin was damaged by means of a pressure of between 15 and 20 kg/cm^2; in a third group the wounds were infected with a culture of staphylococcus aureus. It was found that the formation of leucocytic infiltrates was strongly reduced after total-body irradiation between 600-800 r. The granulation, on the other hand, was less impaired and the regeneration ability of the epidermis hardly affected at all. The phase of demarcation of the wound process was considerably reduced; the second, proliferative-regenerative phase very slightly weakened. With 700 r the formation of granulation tissue was reduced. Even more worthy of attention is the fact that the epithelisation process was not affected even at 800 r. It seems that this process does not immediately depend on the condition of the underlying tissue. The regenerative-proliferative phase of the healing was slowed down in the case of wound infections and the appearance of necroses. With uncomplicated, clean wounds no difference was observed in the healing process between irradiated and non-irradiated animals. Particularly important, on the other hand, is the observation that the healing of wounds which were inflicted during the manifest symptoms of the radiation illness was retarded to a much greater extent than wounds which were caused in the first 2 to 3 days after irradiation. In irradiated mice the infection of wounds shows a tendency toward becoming general.

With a very high local dose of irradiation it is possible for a radiation ulcer to develop in the area of the wound. Such skin defects have a decidedly low tendency to healing. Because of the locally weakened power of resistance of the tissue, there threatens the danger of a purulent infection. Treatment in these cases consists in the application of mild salves and tested antibiotics (18). Should the radiation ulcer fail to heal as a result of conservative therapy, then the only way out is an operation under the protection of antibiotics (19, 20, 21). The excision of the damaged skin area should penetrate well into the healthy tissue with good blood circulation and depending on the nutritional state, into the underlying tissue. Finally the defect should be corrected by plastic surgery. Because of the deficient local blood circulation free transplants and shift grafts have a bad healing tendency. The best results are obtained with jump flaps, especially from the abdominal skin or gluteal region. In order to spare the skin it is recommended that the intervention be carried out under general and not under local anesthesia (20).

A close cooperation between surgeon and nuclear physician is required also in the treatment of bone fractures resulting from radioactive accidents or nuclear weapons explosions. Experiments on rats and mice which were subjected to bone fractures prior to irradiation showed that the formation of callus was reduced at irradiations above 600 r and fully suppressed above 1,500 r. The total healing process was therefore considerably retarded. Doses under 600 r had no effect (26).

Krupko (27) performed experiments with dogs in which the thighs of the animals were broken two hours after an irradiation with 400 to 800 r. Six percent of the animals died within 48 hours, an additional 66 percent within two weeks. Histologically the surviving animals showed a delayed callus formation. In the case of infected compound fractures death occurred during the first five days. With bullet wounds the result was even worse. When the wounds were treated under the protection of antibiotics in local anesthesia, the number of surviving animals increased. For the treatment of fractures marrow-nailing appeared to be an expedient method. Other series of experiments (28, 29) led to similar results. In fractures of the elbow or knee joint or of the radius of rabbits caused 3 to 5 hours after a total body irradiation of 600 r the healing was slowed down due to retarded callus formation, especially in young animals. When the fractures were inflicted 20 hours after irradiation, the healing process was much less retarded.

In the treatment of injured and radiation-damaged persons those experimental findings must be taken into consideration. It is self-evident that the results of animal experiments should be applied to humans only with great circumspection and a certain amount of reservation. No systematization of therapeutic measures is possible. The surgical measures must always be adapted to the nature of the injury and beyond that, to the entire clinical picture and the course of the radiation damage and radiation illness.

In the case of a catastrophic accident it is not always possible to undertake treatment in a scholarly manner; nevertheless the guide lines set forth herein should be considered a goal to be kept in mind at all times.

Summary.

Because of the complexity of the mechanism of damage, injuries

suffered as a result of nuclear catastrophes are of a special nature. Treatment must be based on a correlation of surgical and nuclear medical measures which take into account the conditions of the wound, the amount of radiation received and the clinical picture of the radiation illness. These tasks can be solved only by the cooperation of surgeons, nuclear physicians and physicists. The aim of this work was to provide some guiding lines for such a cooperation.

Bibliography

1. Beck H. R., Dresel H., and Melching H. J., Leitfaden des Strahlenschutzes (Principles of Protection Against Radiation), Georg Thieme Verlag, Stuttgart, 1959.
2. Graul E. H., Strahlensyndrom -- Radioaktive Verseuchung (Radiation Syndrome -- Radioactive Contamination), Verlag Gasschutz und Luftschutz, Koblenz, 1957.
3. Graul E. H., "Metabolic Radioactive Fission Products and Current Status of Decorporation Therapy," in B. Rajewsky: Wissenschaftliche Grundlagen des Strahlenschutzes (Scientific Fundamentals of Protection Against Radiation), Braun, Karlsruhe, 1957.
4. Foreman H., cited in 3.
5. Catsch A., "Distribution and Mode of Action of Incorporated Radioactive Substances, With Special Reference to the Enhancement of Their Separation by Means of Complex Builders, on the Basis of Literature Dealing With Protection Against Radiation," in Schriftenreihe fuer Strahlenschutz, No 5, Gersbach & Son, Braunschweig, 1958.
6. Schmidt H. A. E., "Questions of Protection Against Radiation in the Case of Incorporation of Radioactive Substances," in Schriftenreihe fuer Strahlenschutz, No 1, Gersbach & Son, Braunschweig, 1957.
7. Micke, "First Aid in Radiation Injuries," in Schriftenreihe fuer Strahlenschutz, No 1, Gersbach & Son, Braunschweig, 1957.
8. Hug O. and Muth H., Laboratory Equipment, Work Methods, Protective Measures Against Radiation," in H. Schwiegk: Kuenstlich radioaktive Isotope in Physiologie, Diagnostik und Therapie (Artificial Radioactive Isotopes in Physiology, Diagnostics, and Therapy), Springer Verlag, Berlin, 1953.
9. Gustafson P. E., Marinelli L. D., and Hathaway E. A., Radiology, 59 (1957), 358.
10. Finkel A. J. and Hathaway E. A., J. Amer. Med. Assoc., 161 (1956), 121.
11. Spode E., Dtsch. Ges.Wesen, 32 (1961), 1469.
12. Michon G., C. r. Acad. Sci., 143 (1956), 970.
13. Katayama T., Shikoku acta med., 3 (1952), 231.
14. Bystrova V. V. and Sokolov S. S., Med. Radiol., 3/5 (1958), 71.
15. Sokolov S. S., Vestn. Rentgenol., 31/1 (1956), 30.
16. Hickson J. J., Surgery (St Louis), 34 (1953), 359.
17. Ugoryanskaya V. P., Vestn. Rentgenol., 32/2 (1955), 15.
18. Robinson D. W., Arch. Surg., 71 (1955), 410.

19. Sundell B., Ann. chir. et gynäc. fenn., 46 (1957), 74.
20. Dworiancec H., Wien. Klin. Wschr., (1957), 291.
21. Dufourmental C., Mem. Acad. Chir., 83 (1957), 271.
22. King E. R., Sth. med. J., 53 (1960), 432.
23. Baron H. and Vieten, Strahlentherapie, 106 (1958), 354.
24. Dmitrieva V. S., Ckep. Chir., 3/5 (1958), 41.
25. Tsanev R. G., Markov G. G., and Khristova A. S., Med. Radiol., (Mosk.), 6/4 (1961), 48.
26. von Oeynhausen R. A., Bruns. Beitr., 191 (1955), 110.
27. Krupko J. L., Ortop. Traumat. i Protezir., 19 (1958), 3.
28. Garibadshanian G. A., Ortop. Traumat. i Protezir., 19 (1958), 17.
29. Tkachenko S. S., Ortop. Traumat. i Protezir., 19 (1958), 24.

Address of contributors: Prof Dr A. Moroszek and Dr K. Neumeister, Institute of Radiation and Radiotherapeutic Clinic of the Magdeburg Academy of Medicine (Strahleninstitut und Strahlentherapeutische Klinik der Medizinischen Akademie Magdeburg), Lueneburger Str. 4.

- END -

2451
CSO: 2000-N